AVIATION AND AERONAUTICAL ENGINEERING

AUG. 1, 1920 VOL. IX. NO. 1

Member of the Audit Bureau of Circulations

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THE GARDNER, MOFFAT COMPANY, Inc., *Publishers*

HIGHLAND, N. Y.

HARTFORD BUILDING, UNION SQUARE, 22 EAST SEVENTEENTH STREET, NEW YORK

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ISSUED ON THE FIRST AND FIFTEENTH OF EACH MONTH. FORMS CLOSE FIVE DAYS PREVIOUSLY. ENTERED AS SECOND-CLASS MATTER MAY 19, 1920, AT THE POST OFFICE AT HIGHLAND, N. Y., UNDER ACT OF MARCH 3, 1897.

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AVIATION AND AERONAUTICAL ENGINEERING

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Vol. IX August 1, 1920 No 1

SO much is constantly said in English aeronautical publications about the supposedly advanced position British aircraft design holds in the aeronautical field and of the alleged immense superiority of British designed aircraft—one naturally following the other—that one cannot repress a distinct shock on beholding in a recent issue of a British contemporary the pictures of the aircraft exhibited at the Olympia Show

With one or two exceptions there is not an airplane or a seaplane in the London Show which is not either a commercial adaptation of a war design, or a commercial design produced shortly after the Armistice, and so over a year and a half old. There is a remarkable lack of new developments, not only in aeronautical engineering proper, but also in the commercial design

No attempts can be found toward a more rational utilization of wing surfaces in the shape of strutless wing cellules, or internally braced monoplane wing, or improved wing truss members Nor has this important problem of multiple power plants been touched in the slightest manner. The few multi-engined airplanes exhibited still follow the most orthodox method of carrying their power plant distributed along the wings and hardly accessible units.

In contrast to this disappointing showing, a full page of illustrations in the present issue brings out graphically the real advance German aircraft designers have made toward solving some of the above named problems, and this despite the financial struggles their country is undergoing

But we need not look altogether to Germany to witness practical progress in aeronautical engineering American aircraft designers can, without boasting, point out some of their own creations as highly advanced specimens of the modern flying machine. Without mentioning any particular makes, we can favorably compare various American designed pursuit machines, ground attack planes, ship's scouts, torpedo planes, etc. with the corresponding foreign products And the same applies to purely commercial types, such as mail planes and cabin flying boats

This state of affairs is unfortunately not known to the general public, which might gain in being enlightened to the fact that American aircraft designers, far from being back numbers, have steadily come to the fore front during the last year, until now they hold a position which should be pleasing to all Americans.

A Pneumatic Hangar

A portable hangar of novel design has been built by a French firm. It is an arch-shaped structure of fabric which derives its rigidity not from a frame-work, but from the maintenance of tension in the fabric by means of pneumatic pressure The structural principles involved are those of the non-rigid airship

The advantages of this hangar are that it may be erected quickly by one or two men with the aid of an air pump or blower. The pressure required is small. The erection can be made on unprepared ground. When in use the dead air space between the inner and outer walls forms an excellent heat insulator

The hangar may be taken down in a minute and packed in a small and light bundle for transportation.

The drawback of this construction is obvious, namely, the likelihood of puncture of the fabric, with the resulting loss of shape or collapse of the hangar

Effects of Monoplane Popularity

One of the effects of the return to favor of the monoplane may be to retard the investigation of biplane wing characteristics. Most of the aerodynamic tests on aerofoils have been made on monoplanes and the meager data which have been obtained on biplanes and triplanes show that it is not correct to assume that the "biplane effect" obtained from one wing curve is applicable to another While it has been customary to judge the relative merits of different wing sections from monoplane model tests, there is a strong demand for biplane tests upon which to base such comparisons, and the number of biplane tests—particularly on the more popular sections, is increasing In view of the growing use of monoplanes, there is doubt that the increase will continue

The matter is further complicated by the fact that full scale tests show the difference between biplanes using different aerofoils to be less than indicated by model tests. This puts greater stress on the value of full flight experimentation and less on wind tunnel results.

Airplane Deterioration

Tests were recently made at McCook Field on DH-4 machines which had seen over 100 hr of flying service and had been built for over eighteen months. These machines had seen hard service and had been repaired in a number of places, nevertheless, the tests showed that their strength had remained satisfactory

To those who are interested in airplanes as a means of commercial transportation, the depreciation of the machines has some importance, and it will no doubt be an encouraging bit of news that the loss of strength due to deterioration is as slow as shown

Racing Craft

In building special machines for racing, be they motor cars, yachts or airplanes, the question of safety and utility should always enter The international yacht races just held convince one that exaggeration in design should be watched. A racer should not be allowed to become so extreme that it endangers life or loses its value as an aid to transport development. It is really difficult to draw the line. The machines that enter the Gordon-Bennett contest should embody refinement of design and construction rather than freak or exaggerated structural ideas that get the art of flying nowhere.

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Naval Architecture in Aeronautics*

By Jerome C. Hunsaker, Eng. D.

Commander, Construction Corps, U. S. Navy

As an American, I am pleased to have been asked to read the Wilbur Wright Lecture for this year, and for a moment to stand in the reflected glory of my eminent countryman. Wilbur and Orville Wright were the pioneers who blazed the trail, and made the first clearing in the wilderness. We engineers who follow later are only applying modern machinery and methods of intensive cultivation in their original field. We should, therefore, keep in mind the fact that this field is given to us in trust to keep fertile, that its yield of benefit to mankind shall not diminish.

I have chosen to discuss the use of the tools of the naval architect in aeronautics as I consider that the time has now come to use them. The naval architect is a craftsman with both artistic and scientific traditions, and the art he practises has a technique perfected by the experience of generations.

It is only a few years since the Wrights gave the airplane to the world, but four of those years were years of astonishing activity, and the experience of these years is worth more than that of forty ordinary years There is already a vast store of experience available which the naval architect's methods can analyze, classify and reduce to useful engineering terms.

While aeronautics as a useful art and a science is new, naval architecture is hoary with age Noah probably considered and evidently reached a successful solution of the very problem of animal transport by sea that confronted our naval architects in the Great War. King Hiram of Tyre must have had a very fair naval architect who could fashion ships from cedar of Lebanon with a factor of safety and a range of stability adequate to cope with Atlantic storm waves. Archimedes, however, is generally recognized as the father of naval architecture. He first developed the laws of displacement and buoyancy, and is credited with the construction in 264 B. C. of the Syracusa of 5,000 tons—a veritable dreadnought of antiquity.

The naval architect practises an art with scientific methods. He applies mathematics, especially geometry, in establishing lines, displacement and stability. He applies the methods of the civil engineer in matters of structural design. In matters of resistance and propulsion he is guided by the theory of hydro-dynamics. But in all of these applications, the sure and true guide has been experience. From that remote age when the hollowed-out log canoe replaced the solid tree trunk down to the days of sail and steam, the naval architect has based his new design upon his last. Factors of safety and coefficients of all kinds used in apparently theoretical or frankly empirical formulae have been really factors of experience.

The naval architect's problem deals with the sea, and we cannot pretend to know much more of its mysteries than that Syrian landsman who marvelled at the way of a ship in the midst of the sea. The forces of nature are still unassailable, but the design of a vessel to be staunch and safe is not such a dark and dreadful adventure. Confidence comes from experience and the naval architect's most powerful assistance comes from the scientific analysis of that experience to reduce its lessons to engineering terms.

The naval architect has available a priceless store of learning accumulated by generations of shipbuilders which, with skill and judgment, he can make serve him. He cannot afford to lean too heavily on the past, however, and where a new type of vessel must be produced, imagination and judgment of a high order are necessary. There is an artistic side to naval architecture, and for many craft the artistic feeling or flair of the designer distinguishes an advance in the art from a routine product.

In aeronautics I have yet to see a design representing a marked advance in the art made either without this artistic feeling for form and proportion or made wholly without reference to the lessons of the past.

General comparisons are impossible, but it seems to me that in England aircraft designers have followed the naval architect's methods more than in other countries. This is, perhaps, natural in the first maritime power of the world In England, also, I find a very extensive application of the results of experimental research, both model and full scale, which really is experience interpreted and analyzed by scientific methods.

In France I see less influence of experience and perhaps more originality of invention as shown by occasional radical departures, omitting intermediate steps of development.

In Germany there was once a tendency to "professorial designs" based too strictly on theory, resulting in strange and awkward structures like the Taube types. During the war something happened to reverse this policy, and we saw a series of machines developed step by step, obviously from experience.

In America we have suffered from the designs of the inventor without experience and from the practical rule-of-thumb man without theoretical landmarks to guide him On the whole, the successful designs have been produced by men of imagination and judgment applying analyzed experience with the best theoretical and engineering information available

For very small machines the inventor type of designer has been very successful at odd times. He hits on a good solution, and by a process of cut and try eventually works out the faults before his patience or purse is exhausted For large machines and airships the time and expense required are too great for cut and try methods. A large flying boat or an airship is a success or failure on her first flight. If badly overweight, unstable or out of balance there is no chance to rebuild

In our navy we look with suspicion on the man who is more concerned with the method of doing things than in the actual doing of them, and to avoid any misunderstanding, I must say here that I wish to make my point as to the utility of the naval architect's methods in aeronautical engineering by attempting actually to do a few of the things which appear to be needed at this time This work I have thrown into appendices attached to the paper

Abstract of Appendix I

Both the aeronautical engineer and the naval architect risk their reputations with weight estimates A ship must float on her designed water line and an airplane must fly with the wing surface provided Serious overweight in either case marks a failure It is only rarely that vessels are discovered to be much overweight, but, unfortunately, overweight has been all too common with aircraft Naval architects are able to estimate weights with fair precision from unit weights gleaned from past experience and to check this estimate by calculation from the drawings During construction weights are controlled by weighing everything that goes aboard the ship For aircraft, the practice of rigid weight control has not been well established either in the shop or in the drawing office Very often construction is commenced before the drawings are completed, and during construction changes and alterations are incorporated without reference to their cumulative effect on the weight A proposed change may be approved on its merit and not with reference to a definite weight allowance

It is essential that before construction, or even detail design is commenced, a weight estimate should be made in the nature of a weight allowance which shall be treated like a bank balance and on no account to be overdrawn.

Such weight allowance must be made from the general design drawings before the details are developed and necessarily is based on past experience with a similar type of construction. This is the naval architect's method, and to avoid guess-work requires extensive records and weight returns from actual work.

The matter of weight estimation for various types of airplanes is not really such an inaccurate procedure even in the

* Paper read at the annual Wilbur Wright Lecture of the Royal Aeronautical Society on June 22, 1920.

case of an apparently radical departure from previous types of construction I have assembled published weight data for several hundred different airplanes and seaplanes—British, French, Italian, German and American—from the smallest to the largest, and while the returns in any individual case may be unreliable, the general trend is usually quite definite. It appears that no designer, whether using solid wood, hollow wood or metal, is getting something for nothing, and, in general, the percentage weights for machines of similar type are remarkably alike

If this conclusion be established, a designer may estimate the weights of a new design with some degree of confidence provided he has data for a somewhat similar type to work from In the tables of Appendix I., I have given weight data for machines which are supposed to represent successful designs of adequate strength and power, eliminating all that I know to be weak structurally or grossly underpowered, or otherwise classed as failures. There may, however, remain some types which ought to be eliminated or for which the data is in error However, the plots give little weight to an individual case and are used to establish the general trend of the averages.

I have burdened the paper with the entire mass of data as designers may have use for it in some other form, or may wish to examine more closely the credibility of the evidence. Also, this collection of the weights of present-day machines, in a way, marks the state of the art.

The data is summarized on charts to furnish a guide for use in preliminary design The following general conclusions appear to be established —

(1) The weight of wings, struts, wires and tail surfaces amounts to about 20 per cent. of the gross weight for all types.

(2) The weight of body, fuselage, landing gear, boat hull, etc., trends downward from 22 per cent of gross for one-ton machines to 15 per cent of gross for 20-ton machines.

(3) The weight of power plant also trends downward from 30 per cent for small to 20 per cent for large machines.

(4) The weight light for machines from the smallest to the very maximum sizes has today a lower limit at about 53 per cent.

(5) For large flying boats and large airplanes the weight light is about the same.

(6) The structural weight is high for low-powered machines and low for high-powered machines, and in general the best weight carriers show about 18 lb per horse power

(7) Similarly, the structural weight is high for low wing loading and vice versa.

(8) The wing loading is found to be greater for the larger machines, reaching a maximum of nearly 12 lb per sq ft. for the large flying boats.

(9) It appears that all the evidence from past practice indicates that large flying boats can safely be given a higher wing loading and a higher landing speed than land airplanes, and, hence, have a distinct advantage as weight carriers for commercial purposes.

Abstract of Appendix II

They that go down to the sea in ships are wont to criticize a ship in an off hand manner, her wetness or dryness, her period of roll, whether she will sail sweetly or prove crank, and other mysterious details of her intimate behavior among waves. And all this with an apparent confidence which to a layman must betoken a wisdom such as Solomon's. But there really is little mystery about it, for nearly 175 years ago, Bouguer,[1] the father of theoretical naval architecture, hit upon the brilliant conception of a metacentric height to serve as a measure of stability Since that time thousands of ships have gone to sea with cargoes stowed in an indefinite number of arrangements, and millions of passengers, as well as animals, have been made violently or mildly ill. Some ships carried sail well, others were crank; some ships proved stiff and violent in motion, others capsized. Every sort of marine disaster has occurred and as a result an enormous store of experience has been accumulated In nearly all such cases a knowledge of the metacentric height of the vessel has proved to be a valuable index to her behavior

The metacentric height or distance from the center of gravity to the meta-center is the limit of the distance Gm on Fig. 1 as the angle of roll $\Delta\theta$ from the normal or upright position becomes small.

A ship is stable if there is a righting moment for any angle of heel. The initial stability is measured by the metacentric height in the upright position. If the ship be already heeled through a large angle, she is still stable if she still has a positive metacentric height. There is thus to be considered the problem of range of stability or the angle of heel permissible before the metacentric height vanishes

The period of a roll, neglecting damping, is given by the expression —

$t = \pi k/\sqrt{(g\,Gm)}$, where k is radius of gyration

It appears that the rolling will be quick and hence uncomfortable when Gm is large. For an easy ship Gm should be small, but not so small as to impair the range of stability. For passenger steamers Gm may be made small with safety, but for warships it is necessary to provide a larger Gm than the gunnery officers would desire, to provide for stability in a damaged condition. Battleships sunk in action usually capsize before going under.

I have spoken so far of the "lateral" metacenter which controls the rolling of vessels. There is, of course, a strictly analogous "longitudinal" metacenter which controls the pitching.

The metacentric height is, of course, an index to the statical condition only, but for all practical purposes has served the naval architect very well. The dynamics of rolling among waves[2] are even more elusive than the theory of airplane stability so beautifully developed by Bryan[3] and Bairstow.[4] And just as the naval architect proceeds to design good vessels by using his practical judgment based on experience and a knowledge of the metacentric height regardless of the mathematics of resisted and synchronous rolling, so do we find airplane designers producing good airplanes, using practical judgment and very little mathematics. I have yet to find anyone in a successful airplane design office solving simultaneous differential equations of motion

Unfortunately, the airplane designer has not 100 years of experience to draw on and there has been no ready handle on an airplane to seize upon like a metacentric height. Consequently, a great deal must be left to judgment, artistic feeling, comparison with other airplanes, and eventually to the opinion or prejudice of the test pilot.

The need for some ready means for off-hand judgment of airplane stability and maneuverability has been felt for a long time. The mathematics of stability are too cumbersome for practical use, and require extensive wind tunnel research to establish the necessary constants. It is my experience that we can build and fly a small airplane in less time than it takes to perform the stability calculations.

The general case of the disturbed motion of an airplane is not simple, but the longitudinal or symmetrical motion is two-dimensional and can be considered apart from the lateral or asymetric motion. For the longitudinal motion, we are interested in the pitching oscillations and the criterion that such oscillations be stable. For airplanes of normal design, if there be a righting moment called into play by any angular deviation from the normal altitude,[5] the pitching oscillations so produced are strongly damped. In other words, if an airplane be statically stable it is also dynamically stable, so far as pitching is concerned.[6]

(1) Bouguer, "Traite du navire," Paris, 1746
L Euler, "Scientia Navalis," St. Petersburgh, 1749
Atwood, "Stability of Ships," London 1798
Chas Dupin, "Applications de Geometrie et de mecanique a la Marine" Paris 1822
F J Moreau, "Principes fondamentaux de l' equilibre," etc, Lorient, 1830
J M C Duhamel, "La stabilite des corps flottants," Paris, 1832
H Moseley "On the Dynamical Stability and on the Oscillations of Floating Bodies," London, 1874
F K. Barnes, "On the Metacentre and Metacentric Curves," "Naval Science, Vol III London 1850
E J Reed, "A Treatise on the Stability of Ships," London, 1886.

(2) D Bernoulli (Prix de l'Academie des sciences), Paris, 1757
Dupuy de Lome, "Mem G M, Vol IV, Paris, 1889
Wm. Froude, "Proc Inst. Nav Arch," Vols. II, III, IV, XIV, XVI, London
Rankine, "Proc Inst. Nav Arch.," Vols V., XII, London
Scott Russel, "Proc Inst. Nav Arch," Vol IV, London
Bertin, "Les vagues et le roulis," Berger-Levrault, Paris, 1877.
Resch, "Theorie de roulis etc.," Paris, 1870

(3) G H Bryan, "Stability in Aviation," Macmillan, London, 1911.

(4) L. Bairstow, "Advisory Committee for Aeronautics," R. & M., 116—123, London 1914

(5) A positive value of M_w in Bairstow's notation.

(6) Hunsaker, "Dynamical Stability of Aeroplanes," Smithsonian Misc. Coll. Vol LXII, No 8

My colleague, Commander Wm. McEntee (C. C.), U. S. Navy, suggested the application of the naval architect's metacenter to measure the statical stiffness of an airplane's longitudinal stability. I have assembled the data from all of the wind tunnel tests on complete model airplanes that I had available, and have computed the metacentric height from the observed slope of the curve of pitching moments in the following manner:—

$\Delta M/\Delta \theta$ = slope of curve of pitching moment.
And $M = W \cdot Gm \sin \theta = WGm\theta$, for small angles,
But $M = (\Delta M/\Delta \theta)\theta$
Then $Gm = (1/W)\ (\Delta M/\Delta \theta)$

This algebraic definition of Gm has the dimensions of a length and amounts to from 2 to 12 feet for modern airplanes and flying boats. It is directly proportional to the coefficient M_v of Bairstow's notation, but immensely more easy to remember for use for purposes of comparison. It is also proportional to the center of pressure motion.

Table 1., of Appendix II., gives the metacentric heights calculated from wind tunnel tests on complete models (ex propellers) of 27 types. Airplanes both small and large are included, as well as float seaplanes and flying boats. We have a truly miscellaneous collection, with British, French, German and American examples, which should give a good test of the naval architect's method of classification by means of metacentric height.

Designers have, in general, been giving a greater metacentric height for great chord length, which appears reasonable.

It therefore seems possible from a knowledge of the relation of chord to metacentric height for any design to say with some confidence whether the machine will be more or less stable (stiff) longitudinally than the average, and whether such stability will be reasonable or abnormal.

Effect of Change in Angle of Stabilizer Setting

In Table II of Appendix II are assembled calculations of Gm from wind tunnel tests in which the setting of the stabilizer has been altered.

It is to be noted from these lines that the tractor type tail surface is less efficient than the N. C., a pusher type tail surface, a conclusion consistent with previous experimental work. (A. C. A. R. and M. 438 and 505.)

Effect of Change in Stabilizer Area

The values of Gm for changes in stabilizer area are given for various machines in Table III of Appendix II. These values when plotted against percentage of the original area lie near straight lines. The variation in the slopes of these lines is small and seems to be independent of the original size of the stabilizer.

Fore and Aft Movement of Center of Pressure

In order to study the movement of the center of pressure, the 4 deg. vector location, or line of action of total air force for an angle of incidence of 4 deg., has been determined for a number of machines and for various stabilizer settings. For each machine the points are found to lie near a straight line, the line for the larger machines having, however, a greater slope than those for the smaller machines.

The fact that all of the points so plotted lie very nearly on a straight line indicates that the movement of the 4 deg. vector with change in angle of stabilizer setting is almost entirely dependent upon the wing chord. The average value of the movement of the 4 deg. vector per degree change in stabilizer setting is found to be 0.033 × chord.

This movement is forward if the normally negative angle between stabilizer and wing chord is increased, and vice-versa.

In the foregoing discussion I have tried to bring out the fact than an airplane actually has a metacentric height which is entirely under the control of the designer. It would very much clarify our knowledge of airplanes if we knew the initial metacentric height the designer gave it. Knowing this, we could judge with some degree of confidence whether the machine is reasonably stable for its type. Further, if we knew the metacentric height as designed, the effect of stabilizer adjustment could be considered more intelligently than it is at present.

The adjustable stabilizer is a very useful and convenient device for altering the balance of a machine, but it also alters the metacentric height. It is quite possible, by excessive use of this means to balance up an otherwise tail heavy machine, entirely to destroy the metacentric height and hence the stability. The tables and charts I have given here may prove useful, I trust, in the consideration of such a possibility for a particular design.

Abstract of Appendix III

I doubt if there is any one part of an airplane which has caused more trouble than the control surfaces, rudders, elevators, ailerons. The three rudder system of control invented and developed by the Wrights made flight possible. It is fundamental for three dimensional space. All of the experimenters before the Wrights failed for lack of proper control. Consider the machines which did not really fly of Lilienthal, Montgomery, Langley and the other pioneers. As soon as the Wrights showed how to control an airplane, any boy could make his own glider. Yet, although the fundamental nature of this discovery is universally recognized, we know little more about the design of such control surfaces than the Wrights taught. Control surfaces are proportioned for airplanes and airships largely by judgment and experience. There is no sure calculation in our handbooks, and the designer risks his reputation and the test pilot risks his life on many new machines. For civil aviation it is especially important that machines sold to the general public have adequate control surfaces. This is quite as important as to require adequate factors of safety and apparently not one-tenth so difficult. However, the areas and proportions of control surfaces are the only things not covered by specifications. We depend on the test pilot to state whether he finds the control certain and easy.

When an important feature of design is so largely a matter of judgment and feeling we look to naval architecture for an analogous problem. The rudders of vessels are made large or small, depending on the maneuverability desired. The actual design of such rudders is a matter of judgment and experience. For a merchant ship a rudder area from 1/75th to 1/100th the area of the longitudinal section of the ship is found to be quite satisfactory for ordinary steering. For warships the turning circle is a military feature, and to give quick maneuvering a rudder relatively twice as large is used. The exact size and shape of rudder to use for any design are determined from an analysis of the rudder proportions of ships of similar type whose turning circles and general behavior are known.

The naval architect's method is applied to obtain empirical coefficients for the control surfaces of aircraft of the various types in the third appendix to this paper. I have there assembled data for a large number of airplanes and airships which are generally supposed to be successful. The various machines are classified by type, and the coefficients for each type are averaged in Table I of Appendix III. It is interesting to note that the average coefficients for very different types are practically the same. The coefficients for the individual machines vary more widely and reflect the individuality of the designers. In particular, the average for 15 German airplanes shows an aileron area only eight per cent of the wing area, while the averages for Table I. lie between 11 and 13 per cent. It must be that the Germans did not desire a powerful lateral control.

Table X of Appendix III. shows similar coefficients for the control surfaces of airships. Here we have less uniformity and it would appear that airship designers had not yet settled upon simple rules. However, experience with airships is still relatively limited when we consider the immense numbers of airplanes that have been built.

Turning now to the proportioning of the best control surfaces, both experience and wind tunnel experiment teach that the best control surfaces are narrow trailing portions of fixed surfaces. This makes for simplicity both structurally and aerodynamically. But a difficulty arises in large machines where it is necessary to balance the surfaces to relieve the load on the pilot. I know of nothing more embarrassing than to have a balanced aileron or elevator flutter violently in flight, unless it be to have the balancing portion twist off entirely.

The aeronautical engineer needs some simple rule for the design of balanced control surfaces. It is not practicable to make elaborate wind tunnel experiments for every design and it is not safe to depend too much on judgment. In order to use simple rules, airplane designers must adopt forms which lend themselves to simple computations. Many of the forms of balancing in common use are aerodynamically entirely indeterminate. For example; consider the types of balancing shown on figure 2 of Appendix III. No man can calculate with confidence the force of the air spilling off a wing tip and striking an overhanging portion of aileron. There is certainly a vortex there of a most uncertain nature. Similarly, in the so-called "dove-tail" method of balancing where the balancing portion of the control surface works in a recess in the fixed fin, there is a mutual reaction between the two surfaces which is highly indeterminate. The Zeppelin rudders have until recently had this form of balance, but I have noted with satisfaction that the Bodensee has changed to a partially overhung type of rudder.

The naval architect has long ago been through similar troubles with ships' rudders in rear of the dead wood aft, and concluded that he would use a plane trailing rudder hinged to the stern post with an underhung balancing portion projecting into clean water. The dead wood is cut away forward of this balancing portion. Spade rudders are used where they cannot influence the dead wood or be blanketed by it.

If aeronautical engineers would agree to use simple overhung balanced control surfaces, a simple calculation will serve for their design. Table XI. of Appendix III. summarizes a calculation for such control surfaces on a number of machines where the center of pressure of the trailing portion is taken at 0.3 chord length and for overhung portion at 0.2 chord length. The ratio of balancing to righting moments gives a coefficient which for the normal case free from blanketing or slip stream effects should not exceed .65.

To sum up, control surfaces of the usual type can be designed by use of coefficients taken from similar type machines of normal behavior with every assurance that the maneuverability of the new design will prove normal.

Abstract of Appendix IV

There is nothing more profitless than an argument over a proposed design between the operating personnel, who are always demanding enhanced military characteristics, and the constructors, who are prone to object to change on the grounds that their pet design will be spoiled. Most likely both sides advance very strong arguments to support a particular view of the matter. But such a discussion should not rest on a basis of argument alone else it degenerates into something resembling that ancient impasse "Are the mountains better than the seashore."

As a matter of fact, the effect of any proposed change in military characteristics can be calculated in a sufficiently approximate manner to make possible a decision based upon evidence.

For rigid airships which closely resemble vessels, I propose the use of a naval architect's method for analyzing such problems due originally to that eminent French designer of torpedo craft, M. Normand, and subsequently extended and perfected by Prof. Hovgaard. By Norman's method, a rapid estimate can be made of the cost in displacement involved by almost any proposed change in the ship.

In the fourth appendix to this paper, I have developed Normand's method to apply to airships by forming the so-called weight equation as the sum of the principal weight groups each expressed in terms of the independent and dependent variables of the design. This weight equation is then differentiated to exhibit the effect of a change in any of these variables and formulae deduced, analogous to those which apply to vessels, by which a quantitative estimate can be made for the effect of such change.

An airship can be changed in two ways, by preserving similitude of form and permitting the volume to vary or by holding constant volume and changing the ratio of length to diameter. Considering the first case, the factor of proportionality N computed in the fourth appendix is about 4.5 for a ship of L.49 type. This means that an addition of 1,000 lb. to the weight of any item in the ship calls for such increase in other items, to keep the performance the same that the total lift must be increased 4,500 lb. For battleships N is of the order of only 2.5, indicating a much more favorable situation. The principal reason airships appear to be at a disadvantage comes from the longitudinal members of the hull structure whose weight increases as the fourth power of the length of the ship.

Consider now, the effect of holding volume constant and changing the fineness of the ship. The longitudinal members of the hull vary in weight as the third power of the length and the first power of the diameter, while the weight of the transverse frames varies as the fourth power of the diameter. If the ship be fattened up, weight is saved on the longitudinals and lost on the transverses. But if the ship be too long originally there will result an important net saving in weight.

Finally, I have applied the method to a rigid airship of the Zeppelin type (L.49) as an example to show how practical answers may be obtained. The displacement of L.49 is assumed to be 1,940,000 cu. ft., or 129,800 lb. If it be proposed to make a new design which shall be similar to L.49, except to have 2,000 lb. more bombs, a 25 per cent heavier outer cover, a 15 per cent more speed, the new ship must be given 13,890 lb. more displacement, or a total volume of 2,145,000 cu. ft. The net price paid in displacement is, therefore, about six tons.

On the other hand, if the ratio of length to diameter be reduced from 8 to 7, the ship can be built lighter and the calculations show that a saving in the new design of nearly five tons is due to this change of form alone. As a result, a new ship resembling L.49 might be built having the proposed changes incorporated, and only be slightly larger than L.49, i.e., 1,990,000 cu. ft. The principal dimensions compare as follows:—

Length L.49, 634 ft., new ship 584 ft.
Diameter L.49, 78.7 ft., new ship 83.5 ft.

It would appear that a decrease in the length-diameter ratio is of great advantage, and were it not for the necessity to consider the height of existing hangar doors, airships might well be made fatter than the German models.

Abstract of Appendix V

Naval architects first came into aeronautics in connection with seaplanes. The airplane was developed before the seaplane and at first the great problem was to design the boat or float so that the seaplane could actually leave the water. The early attempts were rarely successful, and it was not until a satisfactory form of planing bottom has been developed by model experiments in the towing basin that any consistent success was had. The contribution of the model basin to aeronautics is too well known to be gone into here. Existing methods and apparatus which had been developed for the study of the resistance of ships were immediately available so soon as it could be demonstrated that Froude's law of corresponding speeds applied to the planing action of flying boats. Such a verification was soon demonstrated by the successful performance of seaplanes designed from the results of model tank experiments.

It is now possible to test in the tank, at small expense and no risk, any proposed form of planing hull and to determine whether or not such a hull is worth constructing full scale. It is, therefore, possible to eliminate a great many types which would prove to be disappointments, and it is also possible to experiment with a great variety of minor modifications in form to determine the effect upon general behavior of these modifications. As a result of the last four years' work at the experimental model basin at the Washington Navy Yard by my colleagues, Commander Richardson and Commander McEntee, two forms have been developed which for general purposes we have found superior to the others. One is a pontoon which has been used on single and twin float seaplanes, and the other is a form of hull which was used for the N. C. flying boats. These forms may not be the best known, as regards resistance or any other single feature, but have proved of all-round utility. With the permission of the Chief Constructor, I am giving the lines and resistance curves for these models in the fifth appendix as they are a very fair representation of the present state of the art.

It will be noted that these forms are both what is called "vee bottom," and although this form of bottom behaves well in rough water and reduces the shock of landing, it is objectionable on account of the spray thrown out from the chine. For a twin float installation, this is often a serious matter as the spray gets in the propeller and causes trouble. A recent

scheme to protect the propeller from spray has been suggested by Grover C Loening For twin float machines, he proposes floats with a bottom sloping outboard from the inner chine This appears to eliminate all spray between the pontoons throwing it outboard.

The experiments in the towing tank record all those things which can be measured, but do not record the spray and wave formation. We have recently undertaken the study of the wave formation which accompanies a planing boat by the use of an ultra-rapid motion picture camera, which takes pictures at eight times the rate of the commercial machine. When projected on a screen at ordinary speed (16 per second), this gives a view of the whole wave system to a microscopic time scale. This work is too new to warrant any conclusions from it, but I mention it as being a suggestive means of studying a very complex state of affairs.

An extension of the usual work of the model basin has led to the investigation of the strength of flying boat hulls to resist the shock of landing. For this purpose, accelerometers are mounted in the hull Attempts to use the R. A F accelerometer were disappointing This instrument had been used in the air for aerobatic flying with very satisfactory results, but it appears that the force at landing is too suddenly applied to be easily measured by this type of apparatus. Another type of accelerometer, developed by Dr A F Zahm, has been used with very consistent results. This instrument depends only on the deflection of a series of light vertical springs by a series of masses and gives a definite maximum

With this instrument landings have been made in smooth water and it appears that the vertical component is seven times gravity and the horizontal component 2.5 times gravity. An R. A. F. instrument mounted alongside the Zahm instrument gave at the same time three times gravity and 1.7 times gravity, respectively. The large vertical components are noteworthy and appear consistent with our experience where engine foundations on flying boats and pontoon struts have failed, although they were designed for a load factor of eight.

Conclusion

In this paper I have discussed in rapid succession five applications of naval architecture which could only be developed in detail in the appendices. Consequently, I cannot expect to have demonstrated more than the existence of these methods of attack and to have advertised their utility. It will be noted that two principal methods only have been used

The first is the *analysis of experience* by means of a comparison of percentage weights, percentage control areas, etc., for a large number of successful aircraft. Similarly an *analysis of experience* is attempted in the comparison of metacentric heights. Normand's method of differentiating a weight equation is also based upon experience, and the method will not attain its maximum value until weight statements for a great many more airships are available

I cannot urge too strongly the general advantage to the art which would result from the full and frank publication of technical information regarding not only successful designs but failures as well The failures in particular are priceless, but perhaps it is too much to expect of human nature that a post mortem on a bad design will see the light of day

The second peculiarly naval architectural method used in aeronautics is *model experimentation* A theory of similitude, geometrical, mechanical or dynamical, is used to apply model basin tests of boat hulls, wind tunnel experiments on aerofoils, and model propeller tests. Such a general use of similitude in design is unique in engineering practice and forms the closest bond between the naval architect and the aeronautical engineer

The *analysis of experience* is really a statistical method for which trustworthy data in quantity are necessary. Given the necessary information, the naval architects' methods not only reveal the past and present state of the art as represented by engineering coefficients and averages, but also show the trend of the more successful designs. In that way, future development can be predicted and the most promising directions for improvement.

To avoid leaving the impression that the naval architect is looking backward exclusively, I should like to take the opportunity to recall the astonishing success of the little airship built by Dupuy de Lome in 1872. This eminent naval architect attained by his professional skill the maximum success which the state of the mechanical art at that time permitted

His little hand-propelled "Aerial Ship" exhibited all of the principal features of our modern non-rigids in their fundamental forms Control and stability were correctly understood and provided for An air speed meter was also provided. The requirements of our modern theory of suspending a car below a non-rigid gas bag were met by his suspension system. A ballonet and blower were used in accordance with good practice More remarkable still, Dupuy de Lome made the envelope of two-ply rubberized fabric and doped it with a very fair gelatine, glycerine, acetic acid varnish to make it tight.

I quote from a contemporary account —(1)

"The stability was something marvellous, several persons moving about in the car at the same time did not produce any oscillation A descent was intentionally made from 1,020 meters to 600 meters without making use of the ballonet. The folds in the balloon then became very marked, and it was interesting to observe the tension of the various ropes as they maintained the major axis of the balloon in a horizontal position

"The complete agreement of the results of the trial with those foretold by the inventor will be obvious to everyone. Such an agreement, usually so rare, is the more extraordinary as in this case all the bases of calculation had to be discovered.

"Henceforth aerial navigation may be said to possess a theory of stability and propulsion. The true history of ballooning will date from the 2nd of February, 1872, a new era marked by the invention of the navigable balloon, and rendered illustrious by the name of M Dupuy de Lome, so well known in connection with scientific progress and invention."

In closing, I should like to express my appreciation of this opportunity to present before this Society some of the later knowledge of the Navy Department in an effort to make at least a small return for the very valuable work which the Royal Aeronautical Society has done in publishing and distributing for the benefit of the art the best knowledge of British Aeronautical Engineers. My Chief, Admiral D W. Taylor, Chief Constructor of the Navy, especially welcomed this continuation and extension of the cordial relations established during the war, and authorizes me to disclose anything and everything of value in the possession of the Bureau of Construction and Repair

The Secretary of the Navy is much pleased that an officer of the United States Navy has been invited this year to read the Wilbur Wright Lecture, and desires me to express his gratification. The foundation of the Wilbur Wright Lecture is an institution very much to the credit of the Royal Aeronautical Society, which is not only the oldest Aeronautic body in the world, but also the first to found a permanent memorial to my countryman. This early recognition of the Wrights by this Society has ample justification, for this very Hall might not still exist tonight had not Wilbur and Orville Wright's invention been overhead to protect it.

In honoring Wilbur Wright, we meet on a common ground Friendly relations between our countries will be furthered by Trans-Atlantic flying, and it seems very appropriate that the most intimate contact should be maintained by those technical and scientific workers who are striving for the same end· the improvement and application of the gift of flight left us by Wilbur Wright.

Catalog of Steel Products

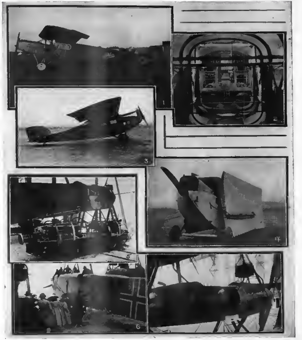
Bruntons, of Musselburgh, Scotland, a large British firm manufacturing a wide line of steel products, publishes a useful catalog of its aircraft specialities. The book consists of a number of loose leaves bound between stiff covers, in a way that permits obsolete material to be removed, and new inserted, thus making it easy to keep it up to date.

A complete line of cables and wires, both plain and swaged are included. The swaged wires are carried in round, lenticular and true streamline sections in a number of standard lengths, of which complete tables of dimensions are given. Wire terminals and universal fittings are also listed.

The book will prove useful to aircraft manufacturers and aeronautical engineers.

(1) Lecleri, Naval Science, April—October, 1873

Some Recent German Airplanes



(1) Fokker Cabin Monoplane; (2) View Into the Engine Room of the D F W Four-Engined Giant, (3) the Sablatnig Cabin Monoplane; (4) the Same With Wings Folded, (5), (6) and (7) Views of the Fuselage and Engine Nacelles of the Staaken Zeppelin Giant

Dynamic Lift and Ceiling for Airships

(Concluded from our last issue)

By Alexander Klemin

Consulting Engineer, Aerial Mail Service and Consulting Aeronautical Engineer

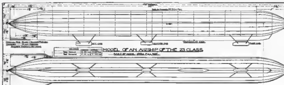


FIG. 3

Dynamic Lift in a Typical Rigid Airship

The model of the rigid airship R 23 in which tests were made is shown in Fig 3

Main Dimensions	Model 1/133 4 Full Size	Full Size
Total length	48 15 in.	535 ft.
Maximum diameter	4 73 in	53 ft.
Volume	0 436 cu ft.	942,000 cu. ft.
Center of volume from nose	23 3 in.	
Horizontal fin area	0.131 sq. ft.	2340 sq ft
Nominal lift		64,000 lb
Percentage dischargeable lift		11.7 per cent
Horse power		1000
Maximum full speed		53 m.p.h.
Static ceiling		3600 ft

Unfortunately, in the model tests carried out on the R 20, none were made with variations in elevator settings, changes in elevator setting necessary to maintain a given angle of pitch increase the resistance and decrease the dynamic lift. The calculations of Table VI, where these effects are neglected, are therefore only approximately correct. The model was always tested without the cars which are present on the actual airship

It is unfortunate that tests have not been carried on beyond a 20 deg pitch, but it is a fairly good assumption that the maximum dynamic effect is reached beyond 15 or 20 deg.

At attitude of maximum dynamic lift this is (13800/64000) x 100 = 21 6 per cent of the gross, a figure only slightly smaller than in the case of the non-rigid.

Theoretical Increase in Ceiling by Means of Dynamic Lift

The actual static ceiling of the R23, as found on test is only 3600 ft., which is explainable by the small value of the dischargeable lift (only 11 7 per cent of the gross) while the dynamic lift at ground level is 21 6 per cent, as we have just seen.

Using the formula $H = 18400 \log \left(\frac{E}{F - f - L_p} \right)$,

with the same significance as in previous paragraphs we find that the ceiling is approximately 2580 m., some 1400 m. more than the static ceiling

Contribution of Rigid Airship Hull to the Dynamic Lift

In the tests on the R 23, normal and longitudinal forces were tested with and without the fins. Since no tests are available for airship hulls in which the angle of pitch is taken into consideration, this gives an opportunity for finding the actual dynamic lift on the hull itself

In Table VII, the results of the tests are modified so as to introduce lift and drag instead of the normal and longitudinal forces given in the report

TABLE VI

Angle of Pitch	Drag Force of Model at 40 ft./sec	Approx speed in ft. with max propeller efficiency (1000 hp.)	Approx speed with correction for propeller efficiency	Lift Force of model at 40 ft./sec	Dynamic Lift (lb.)
0	.06700	82	82	021	+1530
2	06453	83	83	−00217	−150
4	06535	82	82	02026	+1320
6	06965	81 2	81.2	04630	5640
8	07731	78 5	78 0	06799	5950
10	08540	76 0	75 0	12110	7300
15	10100	66 0	63 6	21360	13800
20	.39160	57.0	52.5	43830	16460

TABLE VII

Angle	Lift with fins	Lift of Hull without fins	Lift of fins	Drag with fins	Drag without fins	Drag of fins	L/D of Hull	L/D with fins	L/D of fins	Lift-Coefficient of fins in lbs./sq ft. miles per hour
0	021	00800	01700	06700	068	00300	061	318	2 10	000176
2		01 94		06453	05845	00608	184			
4	.02026	02256	−0230	06535	06088	00497	374	869		
6	04630	03553	01648	06965	06307	00658	532	710	2 40	00017
8	06799	05176	01620	07770	06650	01070	780	1.138	0 24	00037
10	.12110	07795	04335	08540	07369	01180	1 040	1 420	3.70	00045
15	.24140	10875	13910	10100	09900	00200	1.580	2 380	6.05	00188
20	.43630	38500	15330	.29160	19860	06810	1.830	2.150	3.90	.00183

TABLE VIII

Angle	Speed in ft./sec	Dynamic lift due to dirigible with fins attached	Dynamic lift due to hull alone	Dynamic lift of hull as percentage of entire dynamic lift	Dynamic lift of hull as percentage of gross dynamic lift
0	82	0	0		0
4	82	151	172		172
6	81 2	664	244	67	682
8	78 0	595	252	60	55
10	75 0	780	485	66 3	78
15	63 6	1660	885	50.5	1 58
20	52.5	1846	780	58 0	1 22

To compare the efficiency of dynamic lift with the efficiency of buoyancy lift, we can calculate the L/D for the full size ship at 82 ft./sec., the maximum speed.

The buoyancy is 64000 lb The thrust required at 82 ft./sec. is

$$\frac{.06700 \times 133.4^2 \times 82^2}{40^2} = 5150$$

giving an L/D of 12.4

It is evident from this that to employ the dynamic forces on an airship with a view to supplementing its buoyancy is inefficient The fins of the airship also do not give anything like the lift which might be expected from a good wing section or even a double cambered plate. Also presumably owing to the disturbance caused by the large airships, the efficiency of the fins themselves is very poor It would seem as if dynamic effects should be properly used in maneuvering or increasing ceiling only, and not as a means of achieving lift itself

It is interesting to establish as in Table VIII. the proportion of dynamic lift borne by the hull.

Dynamic Effect of Hulls in the Two Dirigibles

The two types are so dissimilar, so many variations are possible in the areas of the horizontal fin surfaces, that no very rigid comparison is possible. It would seem as if dynamic effects would be of about the same order of magnitude for either type.

Table IX. compares the lift which is obtainable from two hulls of the volume of the R23 at a speed of 75 ft. per sec., for the two types.

TABLE IX

Volume 942,000 cu ft. — Speed 75 ft./sec. — Lift 64,000 lb.

Angle of Pitch	Dynamic Lift on Hull of the R23	Dynamic Lift on Hull of the S.S.Z. type of same volume
4	1430	1100
8	3450	6420
10	7500	
12		4550
15	17700	7080
20	27000	[illegible]

It is quite clear from this table that for the same volume a non-rigid will have proportionately far less lift than a rigid. This is evidently to be expected. Since for the same volume the non-rigid will have smaller linear dimensions, and the shape of the rigid is such as is likely to produce greater dynamic lift

It does not follow, however, that because the Zeppelin type hull produces greater dynamic effect, a rigid ship will actually have a greater dynamic effect, the question being complicated by the effect of the fins. Actually we have seen that the proportion of the dynamic lift is smaller for the rigid

On the other hand the dynamic ceiling can be better utilized, since it is not necessary to preserve the shape of the bags on the descent.

Maneuver Possibilities of Dynamic Lift for a Non-Rigid Airship

The preceding calculations show values for the dynamic lift of a non-rigid which are really surprising

Where a non-rigid airship is maneuvered without use of dynamic lift, any variation in the buoyancy produced by such a cause as heating of the airship by the sun's rays, has to be met by expenditure of gas and ballast as well as use of ballonets, if a certain cruising altitude is to be maintained

When the sun's rays heat the gas in the envelope, the pressure increases, the gas escapes and the airship rises. This ascensional movement, which in general is small, is not opposed and after a short time the airship reaches a new position of equilibrium. The airship remains at this altitude until an influence contrary to the first occurs, due to a cooling of the gas, when it begins to descend. A full balloon under these conditions would descend to earth unless ballast were thrown overboard, which would elevate it to a new zone of equilibrium. If, however, when the airship begins to descend, air is blown into the ballonet to compensate for the decreasing volume of gas caused by the increasing pressure, the envelope is kept full During this time, the airship is allowed to descend with moderate speed by small projections of ballast. As soon as the original altitude is again reached, the airship is arrested as quickly as possible by throwing the proper amount of ballast. When the descending speed is overcome, the pilot stops blowing air into the ballonet, partially opens the air valve, and throws a little ballast in order to get a very slow ascent. The airship now rises to the original altitude during which time the ascensional force remains constant because only air is leaving the envelope. When the desired zone is reached the air valve is closed and gas begins to escape from the appendix, the airship coming to rest a short height above the point where the air valve is completely closed.

This somewhat lengthy discussion of maneuvers has been introduced to indicate how even a small disturbance involves skillful and complicated handling of the airship.

If the pilot is in a position to make use of dynamic forces, he can, when the pressure in the envelope is increased by heating, impose a downward load on the airship, and bring it to a zone below the original zone of equilibrium, where the excess buoyancy will be met by the negative dynamic lift. During this descent there will be no escape of gas, since the greater pressure of the gas will be met by the greater pressure of the atmosphere.

Similarly if the airship passed into a zone where the air was warmer and at a greater pressure than the gas, the envelope would lose its form unless air were blown into the ballonets to compensate for this, and this would cause a descent. To retain the original altitude, ballast would have to be thrown overboard, although it might be possible to rise by simply opening the air valve and to lose no gas. The dynamic lift would in this case possibly save ballast and certainly save maneuvering.

It has been indicated how dynamic lift can be employed to check departures from a required altitude zone.

It is also quite possible to use the dynamic lift so as to rise above or below an equilibrium zone. Particularly in conjunction with the use of ballonets are there advantages in using the dynamic lift. If the pilot wishes to rise when the ballonets are partially full, all he has to do is to open the air valves and head his ship up The ship will rise, the ballonets will empty and the gas expand. Subsequently, by using negative dynamic lift and blowing air into the ballonets, the original altitude can be reached without expenditure of either ballast or gas. For a descent the ballonets alone are sufficient, and the rate at which the ballonets can be filled with gas limits the descent, as otherwise the airship will lose its form.

On making a departure dynamic lift can also be used to advantage As calculations have shown its value is very high. Unless it is desired to make a purely vertical ascent, in which case ballast must be employed of necessity, the initial dynamic lift can be utilized to secure any rate of ascent required to the capacity of the gas valves.

Whereas with the use of ballast an airship always acquires a certain ascensional velocity which carries it beyond its proper equilibrium zone—involving careful maneuvers and loss of gas as we have just shown—with the use of dynamic lift complete control is possible, and the airship can be made to reach any desired altitude with no excess loss of gas. The amount of increase in ceiling which it is possible to attain by dynamic

action is really surprising. Unfortunately, during the ascent past the static ceiling there is further loss of gas.

If the ballonets are so arranged as to correspond to the ballast, then on the descent there will come a point when the amount of gas in the envelope will no longer suffice to maintain the shape of the airship. At such a moment the dynamic lift will diminish and consequently equilibrium will be seriously broken.

It is only possible, therefore, to use dynamic lift in a nonrigid: (a) to the point above the ceiling when the safety valves begin to work, (b) to enlarge the ballonet volume far beyond that corresponding to the ballast, this meaning extra weight in ballonet fabric and attachments. The extra weight of ballonet would be amply justified by the enormous increase in ceiling possible.

Dynamic Action in Airships Not Equipped with Ballonets

We will consider next the rigid type not equipped with ballonets. A Zeppelin with a number of bags in the different cells illustrates this type.

If, for special reasons, the first equilibrium position is assumed to be as low as possible, then only is it best to start off with a full balloon, since at any altitude at which equilibrium is to be maintained it is better to navigate with a full balloon. For a small initial altitude it is better not to complicate the piloting problem by starting off with a flabby balloon.

In any other case, it is better to start off with a flabby balloon. If the balloon is full at the start, a correspondingly greater amount of ballast must be carried. Otherwise there would be an excessive rupture of equilibrium at the start, and the possibility of a rise too rapid for the escaping gas, with consequent danger of bursting. If, therefore, the balloon is full at the start of the voyage, a great deal of cumbersome ballast must be carried, which imposes a troublesome duty on the pilot—the entire surplus ballast having to be thrown overboard. With a flabby balloon the initial rupture of equilibrium may be greater than in the case of the full balloon. Since during the passage from the flabby to the full balloon, the buoyancy remains constant, and not only is the initial rupture of equilibrium greater, but it also acts on a smaller mass, since there is no excess ballast to be carried. The free balloon will thus have a much greater ascensional velocity, which is important in making a safe get-away and possibly for military reasons. There is also less waste of gas than in the case of the full balloon.

For these reasons it may be safely said that a rigid airship will always be used as a flabby balloon in its initial stages.

The first important part played by the dynamic forces on the airship is in securing the maximum rate of ascent. With flabby envelopes the initial rate of ascent is not limited in any way, and the effect of the initial rupture of equilibrium may be increased largely by pitching the airship suitably and giving it forward velocity.

Whether a balloon rises as a flabby or as a full balloon, it accelerates rapidly at first, then attains a constant velocity which carries it beyond the point which the rupture of equilibrium due to the throwing overboard of a certain amount of ballast entitles it to. While the velocity of ascent is being spent, the balloon is losing gas unnecessarily. When the velocity of ascent is spent, the balloon is at an altitude where the buoyancy is insufficient and it will descend to earth unless a certain amount of ballast is thrown overboard.

Here the dynamic lift may again be made to intervene. The airship may, when the altitude of equilibrium is about to be attained, be put into an altitude of negative lift, thus preventing the loss of gas taking place during the spending of the ascensional velocity, or it may be made to replace the ballast by giving the airship a positive or upward lift.

Particularly with military or naval airships, it is important to carry as large a useful load as possible, and at the same time to reach the highest possible ceiling. The dynamic lift may be made to intervene to secure a useful increase in the ceiling.

When an airship has reached its maximum altitude, if any loss of buoyancy results, it descends to the ground, as is well known, unless this is checked by throwing overboard some reserve ballast. The utilization of dynamic lift avoids the necessity of this reserve ballast being carried.

When an airship is in equilibrium at its maximum altitude, or at any intervening altitude, sudden disturbances may arise due to the action of the sun on the passing of the airship into a strata of colder air. A disturbance of this character, for instance the heating of the gas by the sun, means a rise in altitude, with subsequent drop when the gas cools off, if no ballast is thrown overboard. If ballast is thrown overboard there may be no serious drop, but there is still loss of gas on the ascensional movement. The dynamic effect may be made to check both the loss of gas and of ballast.

On descent the negative lift can be made to take the place of ballonets to a certain extent.

Summarizing, dynamic action may be of use for a rigid airship in:

(1) Increasing ascensional velocity.
(2) Checking a passage beyond the altitude of equilibrium due to ascensional velocity.
(3) Increasing ceiling.
(4) Checking disturbances at any altitude and decreasing reserve ballast and loss of gas.
(5) Facilitating descent.
(6) Overcoming obstacles.

Variation in Magnitude of Dynamic Effects with Size of Ship For Similar Ships

If the dimensions increase, and the speed remains constant, the dynamic effect will increase with the square of the linear dimensions while the volume will increase as the cube of the linear dimensions, so that the dynamic effect will decrease as a proportion of the gas buoyancy. But, as the dimensions of an airship increase, its speed increases also, if the weight and power of the engines bear the same proportion to the total weight for ships of similar resistance coefficients.

This can be expressed by simple equations referred to the linear dimensions of similar ships.

Thus $C_1 l_1^3 =$ B H P for a ship of given size

and $C_1 l_1^3 = C_2 l_1^2 v_1^3$

where v = speed

and C_2 is a constant.

For a similar ship of linear dimensions l_2

$C_1 l_2^3 = C_2 l_2^2 v_2^3$

$$\text{therefore } \frac{l_2}{l_1} = \left(\frac{v_2}{v_1}\right)^3$$

$$\text{and } \left(\frac{v_2}{v_1}\right)^2 = \left(\frac{l_2}{l_1}\right)^{2/3}$$

The dynamic effect is proportional to $l^2 v^2$ and the ratio of the dynamic effect to the gross buoyancy $\frac{l^2 v^2}{l^3} = \frac{v^2}{l}$

The ratio of this ratio for two ships is therefore

$$\frac{v_1^2}{l_1} : \frac{v_2^2}{l_2} = \frac{v_1^2}{v_2^2} \times \frac{l_2}{l_1}$$

Substituting the expression for $\left(\frac{v_2}{v_1}\right)^2$

$$\text{we get } \left(\frac{l_1}{l_2}\right)^{2/3}\left(\frac{l_2}{l_1}\right) = \left(\frac{l_2}{l_1}\right)^{1/3} \text{ if } l_2 > l_1$$

$$\left(\frac{l_2}{l_1}\right)^{1/3} > 1$$

It follows that the dynamic effect will be smaller for larger ships, but the decrease will not be very rapid.

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A Grant for the Gottingen Laboratory

The bill of the German Traffic Office includes an item of 15,000 marks as a contribution towards the maintenance of the Gottingen Test plant, which is considered most important for the development of German aviation, if the latter is to compete successfully on the world's market.

Variable Wing Area and Variable Camber

By H. B. Irving, B. Sc., A. F. R. Ae. S.

The extremely rapid progress which the science of aeronautics has made during the last decade has led many to take it for granted that progress will be equally if not much more rapid in the near future. In the light of the present state of knowledge regarding aircraft the writer is of the opinion that the probabilities of the case do not, however, point in this direction. There will undoubtedly be huge strides made in the applications of aircraft to commerce, transport, sport, etc., but in the airplane and airship themselves it would not appear that any revolutionary changes either in design or performance are probable. The period of rapid strides seems to have given way to the period of comparatively slow development and improvement, each inch of advance along the line of progress being won by close observation of collective experience or based on the results of careful refinements of research.

What the actual lines of development of the future will be is a matter of much speculation. As regards the power plant careful consideration is now being given to and estimates made of the possibilities of steam propulsion of aircraft. But unless some new discovery is made, any change in the motive power would be accompanied neither by a great advance in performance nor by any notable economy of fuel. Perhaps one of the greatest advantages which might be gained by change of power unit would be that of increased reliability, and to this might be added increased period of service.

Methods of Improving Airplane Performance

In the airplane there are two methods of improving performance which, although generally recognized, have not yet been put into common practice owing to the mechanical difficulties involved in their application. The two methods referred to are to some extent virtually the same: one is to increase the wing area when about to land; the other is to increase the maximum lift coefficient when landing. In the former method a means of obtaining variable wing area is sought, in the latter—since, generally speaking, wings with a large camber have higher maximum lift coefficients than wings of small camber—a means of obtaining variable camber. So much thought is being given by aeronautical engineers to these problems that the future will surely bring forth a solution of one or other, if not both, of them.

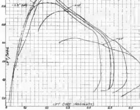


FIG. 1. BIPLANE WITH FLAPS

Three possible ways of altering wing area may be mentioned. The upper and lower wings of a biplane for instance, might conceivably be made so as to allow of their gradually being brought closer and closer together until the lower wing fitted snugly under the lower surface of the upper wing, thus in effect converting a biplane into a monoplane. Another method would be to have part of the wing surface of an airplane to fold back into or against the fuselage, while in a third method the wings or parts of them might be made telescopic in the direction of the span. This is a development which could only be hoped for in wings made of metal.

As has already been mentioned, the means of obtaining an increased maximum lift coefficient have generally been looked for in some practicable method of varying the camber of the wing. So far the only method seriously contemplated for doing this has consisted in hinging the rear portions of the airplane wings about an axis just behind the rear interplane struts, thus forming "flaps" whose angle relative to the wing can be adjusted by the pilot. At top speed the position of the flaps should be a few degrees above normal position while when landing they are lowered about 20 deg. or so.

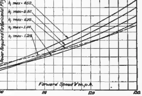


FIG. 2. EFFECT OF VARIABLE MAXIMUM LIFT COEFFICIENT ON TOP SPEED: HIGH SPEED AIRPLANE

As far back as 1914 an experimental airplane was constructed on these lines at the Royal Aircraft Factory, Farnborough, England. The flaps were divided at the center of the airplane and were connected to the control column in a similar way to that of ordinary wing ailerons, so that movement of the column to one side caused the flaps on one side to rise and on the other to fall. At the same time both flaps could be raised or lowered together by means of a handwheel. Thus, the flaps could be set up or down without interfering with the lateral control of the airplane. The conclusion arrived at from tests of the machine was that the advantage derived from the use of the flaps was hardly great enough to outweigh the disadvantage of the extra complication in the control.

Although it is fairly common knowledge that both variable wing area and variable camber are highly to be desired in an airplane, understanding as to the exact way in which these are beneficial is often very vague and loose. It will therefore be the object of the subsequent part of this article to give, first of all, a clear conception of the aerodynamics of the variable wing area or variable camber machine, following this up by examples which will give a quantitative idea as to the effect of variable wing area or camber on performance.

Aerodynamics of the Two Methods

When a machine is about to land, it flies at the attitude which corresponds to maximum lift coefficient. For best rate of climb the airplane flies at (very nearly) the attitude which gives the highest lift/drag ratio, and since at this attitude the

lift coefficient is less than the maximum, the airplane has to fly faster than when landing in order to satisfy the essential condition that the lift shall be equal to the weight of the airplane. At the attitude of maximum lift/drag ratio the horsepower required for horizontal flight is near the minimum leaving the maximum margin available for climbing at the speed corresponding to this attitude. If, however, instead of the extra available horsepower being used for climbing it is employed in propelling the airplane at greater speed horizontally, then, the lift coefficient required at the high speed being less, the airplane flies at a smaller incidence and with a smaller lift/drag ratio, which means of course that it flies at a reduced aerodynamic efficiency. It might at first sight be thought—why not design a machine so that its attitude at top speed corresponds to maximum lift/drag ratio? But a

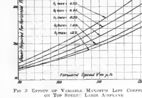


FIG 3 EFFECT OF VARIABLE MAXIMUM LIFT COEFFICIENT ON TOP SPEED LARGE AIRPLANE

moment's thought shows that such a machine would be able to fly at one attitude and one attitude only, that is, it would have no speed range.

Now consider an airplane which is flying horizontally at top speed, and suppose that by some means its wing area is reduced If the speed remains the same the angle of the wings must increase in order to meet the need for increased lift coefficients on account of decreased wing area. At the same time the lift/drag ratio increases and the horsepower required for flight goes down, so that the airplane could fly at a still higher speed. It is precisely in this that the advantage of variable wing area lies.

Now turn to the variable camber machine Here is a double effect. First, there is the increase in maximum lift coefficient due to moving the flaps down. This means that, for a machine of given landing speed, less wing area is required and therefore, for a given speed near top speed the lift/drag ratio is greater, and the horsepower required less, than for the normal machine. Second, movement of the flap slight- of efficiency This is illustrated by Fig 1 which shows the effect of various settings of the flaps on the efficiency of a biplane of R. A. F. 15 wing section with flaps hinged at 0.22 of the wing chord length from the trailing edge. The dotted curve is the envelope of the curves for all settings of the flaps and it is this curve which is in effect the characteristic curve of the wing with hinged rear portion. It is clearly seen from the figure how at the low speed end of the curve the maximum lift coefficient is increased and that at the portion corresponding to high speed there is an increase in efficiency

Quantitative Estimation of Performance

Passing to a method of estimating quantitatively the difference in performance of two machines of a given landing speed, similar in all respects save that one has fixed and the other variable wing area. Let us suppose for the moment—at the same time bearing in mind the supposition—that the weights of the two airplanes are the same.

The resistance of an airplane can be considered to be made up of two parts, one part being that due to the wings, which alters with angle of incidence, the other that due to the body, etc., which remains sensibly constant for normal flying altitudes of the machine.

Let k_l = lift coefficient of the wings
k_d = drag coefficient of the wings
k_l max. = maximum lift coefficient of wings
V = forward speed of machine in m.p.h.
R = resistance of body and parts other than wings.
W = weight of airplane in lb.
ρ = density of air in slugs per cu. ft.

From the definition of k_l we have—

$$k_l = W/\rho AV$$

so that if, for the machine with variable wing area, k_l is calculated on the basis of the smallest wing area, it will have a fictitious value at the landing speed (when the maximum area is brought into operation) which will be greater than the true maximum lift coefficient in the ratio of the maximum to the minimum wing areas. The effect of variable wing area may thus be considered virtually to increase the maximum lift coefficient of the wings.

A simple expression for the power required to drive the airplane horizontally will now be obtained in terms of the forward speed V and the lift/drag ratio of the wings.

Total resistance of airplane = resistance of wings + resistance of body etc

$$= (W - k_l/k_d) + R.$$

$$\frac{\text{Power required}}{CW} = \frac{V}{k_l/k_d} + \frac{RV}{W}$$

where C is a numerical constant.

If values of V are chosen, k_l can be calculated from the relation

$$k_l = k_{l\,max} \times \left(\frac{V_s}{V}\right)^2$$

where V_s = speed corresponding to maximum k_l and from k_l the value of k_l/k_d can be read off the characteristic efficiency curve for the wings of the airplane Hence

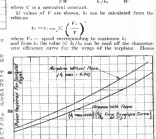


FIG. 4 EFFECT OF WING FLAPS ON TOP SPEED HIGH SPEED AIRPLANE

the power absorbed by the wings can be found For the present purpose the power absorbed by the body is best obtained from the estimated relationship between resistance of body and wings as explained in the examples given below

First Example

The first example relates to a high speed machine whose stalling speed is 50 m.p.h. and top speed, with fixed wing area, 120 m.p.h. The object of the calculations is to find the power required for horizontal flight at various forward speeds and with various ratios of maximum to minimum wing area as represented by various maximum lift coefficients. The results are shown by Fig 2 in which power required to drive the airplane is plotted against forward speed.

It should here be explained how the figures for the power absorbed by the body etc. were obtained. For an airplane of this type it is known that at top speed the powers absorbed by the body etc. and by the wings are about equal. In the table it will be noticed that they have been made equal at a speed of 120 m.p.h. The power absorbed at other speeds was found simply from the fact that power varies as the cube of speed for a body whose resistance varies as the square of the speed.

Returning to Fig. 2 the line of constant power which cuts the curve for the machine with fixed area at a point corresponding to a forward speed of 120 m.p.h. shows how the top speed is increased in the machine with variable wing area. If the wing area could be doubled, for instance, on landing, the curves show the increase in top speed to be not more than about 8 m.p.h.

Second Example

A second example is graphically shown in Fig 3 This applies to a type of machine with landing speed of 50 m.p.h. and top speed 100 m.p.h., at which speed the resistance of body etc. is taken to be 75 per cent of the resistance of the wings. The increase in top speed due to possible doubling of the wing area on landing is here about 9 m.p.h.

Rate of climb, although not so important for peace time requirements as it was in time of war, is yet worthy of consideration, and it is not hard to see that the machine with variable wing area has not the slightest advantage as regards rate of climb over the fixed area machine. An airplane climbs at its fastest rate when it is at the attitude corresponding to maximum lift/drag ratio of the whole machine If the wing area is reduced, not only is the maximum lift/drag ratio of the airplane reduced in consequence of the greater proportion of body resistance to wing resistance, but the speed of the airplane at its attitude for best climb is increased, there is therefore a double increase in the power required for horizontal flight at the attitude for maximum efficiency, and in consequence, less power available for climbing So that, even if an airplane has reducible wing area it is of no advantage to it so far as maximum rate of climb is concerned.

In so far as variable camber affects the maximum lift coefficient its effect is just the same as variable wing area. But, as has already been explained, variable camber affects the efficiency of the wings over their whole range of angle of incidence. The effect on top speed may be studied in exactly the same way as for the variable area machine except that corresponding values of lift coefficient and lift/drag ratio must be taken from the "envelope" curve of Fig 1. The result of doing this is given in Fig. 4 for the case of the high speed airplane with flaps The curves show the increase in top speed to be about 5 m.p.h. as against 9 m.p.h. for the machine with the same virtual maximum lift coefficient obtained by the use of variable wing area. The effect of variable camber on climb would be small but probably adverse, maximum lift/drag ratio being increased very slightly by use of the flaps, but reduced on account of the smaller size of the wings as compared with the body in the machine with wings of variable camber.

Conclusion

It cannot be said that the results of this examination into the effect on performance of variable camber and variable wing area offers very great encouragement to the aspiring inventor Any quantitative estimate as to effect on performance must necessarily be rather rough since in a general treatment of the subject it is not possible to take into account all the various factors For example, variation of wing area might involve at the same time variation of aspect ratio of the wings. And weight has been taken as constant for the various machines. This means that unless the wings, together with the mechanism for altering either area or camber, can be made the same weight as ordinary wings there will be a difference in the useful loads carried by the machines In the case of the machine with variable area it would hardly seem possible that the wings and their mechanism should be no heavier than ordinary wings, but in the case of the variable camber machine the weight saved on the smaller wings might compensate for the weight of the extra mechanism required to alter the camber. So that in the former case especially, the estimated effect on performance would probably err on the big side if applied to machines of a given useful load carrying capacity.

Tests of Fireproof Airplane Dope and Equipment

(Report of the Fireproof Test Committee American Flying Club)

Object

To determine whether the fireproof airplane dope and the fireproof airplane equipment, consisting of a flying suit and gasoline tank, invented by Parker R. Bradley, of the Aircraft Fireproofing Corp., Nutley, New Jersey, are non-inflammable.

Time, Place and Witnesses

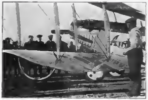
The tests were conducted on May 28, 1920, between 4 and 7 p.m. at the Atlantic City Airport, Atlantic City, N. J., by the Fireproof Test Committee of the American Flying Club The members of the Committee were —John J. Rooney, chairman, Col. Gerald Brant, Lt. Col. H. E. Hartney, L. T. Driggs, Arthur Joline and M. G. Geary. The tests were witnessed by Mr Bradley and Capt. J. G. Hope of the Aircraft Fireproofing Corp. and a large number of spectators.

Description of Airplane and Equipment

The fire testing of the dope and gas tank involved the testing of a complete airplane specially treated by the Aircraft Fireproofing Corp The airplane was a new Springfield Aircraft Corp. Model JN4D2 With the exception of the fireproof treatment, the airplane was identical to the standard model. All woodwork was painted with Bradley's Fire Proof Paint. The paint was applied over previously finished surfaces, and was not absorbed by the wood fibres. It is Mr Bradley's plan to impregnate wood with his Fire Proof Paint and eliminate the use of both filler and varnish, which is otherwise required The paint used had a creamy color, however, it can be made in any color desired.

The covering of the wings and control surfaces was Grade A mercerized cotton, and of the fuselage Grade B linen. Each piece of covering was treated with a liquid fire proofing solution, by a secret process, before it was put onto the wood work. Experiments made by Mr Bradley show that this liquid solution will make fabric fire proof without the addition of other fire proofing treatments. The wings and control surfaces had three coats of Bradley's Fire Proof Dope, and three coats of Bradley's Fire Proof Paint. The fuselage covering had four coats of Bradley's Fire Proof Paint. The inner side of the fuselage was neither doped nor painted The wings had a very unique feature consisting of an inner covering under their upper surfaces. This cloth was put on the wings before the upper cap strips of the ribs were fastened in place The covering was Grade C plain cotton and was treated with three coats of Bradley's Fire Proof Dope. The object of the inner skin was to give the wings double protection against fire and deterioration. An inner covering of this kind will obviously not be affected by either the sun or other elements, hence the cloth should always be taut and in perfect condition. In case of a mechanical accident to the outer skin, an inner skin would apparently be capable of sustaining the airplane. There was a ¼ inch air space between the two skins. The chief object of this air space was to check carbonization of the inner skin in case intense heat was applied to the outer skin. The Fireproof dope was of the same color as the Bradley Paint.

The gas tank which was designed by Mr. Bradley to complete the fire proofing of the airplane was cylindrical in shape, and of 17 gal. capacity. The tank was made of 22 gauge template and covered by the Braedner process with ⅛ in. of sheet rubber. The rubber was covered with a ¾ in layer of hair felt painted with five coats of Bradley's Fire Proof Paint and one coat of varnish The object of the rubber covering was to make the tank leak-proof; of the felt to make the tank heatproof, and of the Bradley paint to make the tank fire proof. All the gas lines were similarly fire-proofed.



SPRAYING A JN-4 WITH GASOLINE DURING THE TESTS OF MR. BRADLEY'S FIREPROOF DOPE

Besides the gas tank, dope and paint, a fire and heat proof flying suit invented by Mr Bradley was also tested. This suit consisted of a helmet, coat and trousers. The helmet was made of sheet aluminum covered with a 3/8 in. layer of hair felt painted with three coats of Bradley's Fire Proof Paint. Attached to the bottom of the helmet was a skirt of cloth, fire proofed by the Bradley process, which tucked inside the suit proper. Air was forced into the helmet by means of a pipe which had its open end in the propeller blast, and exhausted from the helmet through a second pipe. The exhaust pipe had a gauze covered end which prevented the fire from entering the helmet. The helmet had a small window of two thicknesses of 1/8 in. mica with a 1/4 in air space. The suit proper was made of 1/3 in. sheet asbestos with a 3/8 in. inner lining of hair felt. The felt was lined with fire proofed cotton. Both shoes and gloves were made of the same material as the suit. The weight of the suit with the helmet was 15 lb.; however, it is thought that this weight can easily be reduced to about 10 lb. with only a few refinements.

Method of Testing

The flying suit was tested independent of the airplane. One suit was tested on Mr Hugh Gordon Campbell and one on Mr Charles W Kerwood. Each suit was sprayed with gasoline and then ignited. The fire was not concentrated but covered the whole surface of each suit. The flames were of sufficient intensity to heat and set fire to any combustible material; however, the pilots displayed no discomfort, nor did either suit show any indication of damage.

The complete airplane, including the inside of the fuselage was sprayed with gasoline, then ignited. The flames covered all the surfaces, struts and cables, and continued until the gasoline was consumed. The flames acted on the surfaces the same as flames act on non-combustible material. Neither the cloth nor the woodwork were affected by the flames, other than a few blisters on the struts, due to an outer coat of varnish. Besides being unsightly, the blisters were of no significance as they did not affect the fire proofing qualities of the airplane.

The second experiment consisted of attaching flaming torches made of waste soaked in gasoline, to the wings, and having Messrs. Campbell and Kerwood fly the machine. The torches made large flames and continued to burn with intense heat while the machine was in the air. There were no indications of fire when the plane was inspected after landing other than a little soot on the under surface of the upper wing, and the few blisters previously noted.

Conclusion

The tests show conclusively that the Bradley Fire Proof Flying suit will not catch fire and burn when soaked with gasoline and ignited, and that the suit is comparatively heat proof. The advantages of a suit of this design, in aviation, are too obvious for enumeration, and it is most unfortunate that one was not available during the war. It appears that this suit could be used to advantage in other lines of service and industry, such as fire fighting and furnace work.

The tests also show that the Bradley Fire Proof Paint and Dope are non-inflammable and may be depended on to keep fire from spreading and damaging both cloth and wood. This dope and paint will not prevent intense heat from carbonizing cloth and wood, because such heat resistance is impossible; however, it affords a fire protection for airplanes heretofore unobtainable. The Bradley Fire Proof Dope gives fire protection without sacrificing the strength or adding much weight to the airplane.

Mr Bradley and his associates deserve much credit for the development of these products, which will unquestionably greatly improve the construction and safety of aircraft.

Book Review

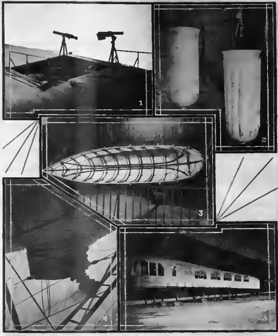
ALL THE WORLD'S AIRCRAFT, 1919. Edited and compiled by C. G. Grey. With all the world's aeroplanes, aero-engines and airships. Sampson Low, Marston & Co., London and Edinburgh.

One who is not familiar with previous editions of this book will wonder at its imposing title, which however is justified to a surprising extent. The completeness with which the vast field of description and illustration has been covered is truly remarkable. Some of the information, especially that concerning machines which are not well known, is of doubtful accuracy. Of course this is only to be expected by those who know the difficulties of collecting such a tremendous mass of aeronautical data. Nevertheless, the work as a whole is very valuable on account of the great number and wide distribution of machines listed.

The volume is divided into three parts devoted respectively to airplanes, airships and aeronautical motors. The first part naturally is the largest, and is arranged by countries in alphabetical order preceded by an historical sketch. The amount of information given on the different machines varies widely, and is in the form of descriptions, tables of main dimensions, weights, performance, photographs, scale drawings and sketches of important features.

CENTRAL PORTION OF THE PARNELL PANTHER SHIP'S SCOUT
(C) *Kadel & Herbert*

Details of German Airship Construction



(1) UPPER GUN STATION ON ZEPPELIN L.12—(2) BALLAST BAGS, HOLDING 200 KG OF WATER, OF A PARSEVAL. THE ONE ON THE LEFT IS FULL, THE ONE ON THE RIGHT IS EMPTY.—(3) INTERNAL VIEW OF A BUMPING BAG USED ON A PARSEVAL.—(4) PARSEVAL TYPE GAS VALVE AND AIR VALVE.—(5) PASSENGER CABIN OF THE NEW ZEPPELIN LINER NORDSTERN

Automatic Cinematograph for Aerial Surveying

By Alfred Gradenwitz

AERIAL SKETCH OF VERONA, ITALY, MADE WITH A SERIES-TOPOGRAPH

During the last years of the Great War German aviators achieved some remarkable results in aerial mapping in connection with observation flights. This was made possible by the so-called Series Topograph, a cinematograph camera which on a roll of film automatically produces a series of views of the ground flown over. The individual views follow one another so rapidly that the successive pictures, which overlap each other at their edges, form, when combined a continuous record of the ground.

On account of the small weight of the film enough photographic material can be taken on board an airplane to allow several hundreds of views to be taken during a single flight, than photographing the whole area covered.

Recent improvements in this apparatus have further extended the usefulness of the Series Topograph, which now permits to record during a 4-hr flight, the following areas:—

Area	Scale
[illegible] sq km	1 10,000
1700 sq km.	1 20,000
[illegible] sq km	1 30,000
2700 sq.km	1 40,000

By maintaining a constant altitude throughout the flight, it is warranted to assume a constant scale for the entire series of pictures.

The vertical records of the ground have the advantage of being absolutely true to nature and, in opposition to maps, rendering all details in their characteristic form with the utmost accuracy, whereas plans heretofore in use are devoid of any characteristics, showing at most a map skeleton. Towns, villages, houses, lakes, rivers, canals, roads, railroad lines, fields, woods, trees, etc., now take the place of dead conventional marks.

AERIAL SKETCH OF THE PIAVE RIVER, MADE WITH A SERIES TOPOGRAPH

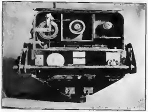
The Series Topograph actually shows the "face" of the ground and can be used for the following purposes

(1) Preparing town and traffic maps, tourists' maps and the like, the main advantage of the process being due to the faithful rendering of the ground as above refered to

(2) As a base in making up plans in road, railroad and canal building, river regulation, etc. These records, as obtained during a single flight, will, especially in countries not yet surveyed, ensure an enormous saving of time and expense

(3) For naval purposes, e. g., preparing sea and harbor maps, for clearing and dredging operations, reconnoitering of sand, shell and coral banks, shoals and coast alterations, flooded areas, etc.

ABOVE: FILM CUTTING AND GLUING FRAME—MIDDLE: SERIES-TOPOGRAPH ACTUATED BY AIR PROPELLER—BELOW: WINDING THE FILM ON THE DEVELOPING FRAME



SERIES-TOPOGRAPH WITH THE SLIDE CASE OPENED

(4) For preparing aerial sketches of the ground to be used either as a substitute for accurate maps, especially in countries not yet surveyed, or for supplementing the data used in preparing accurate aerial maps.

The main parts of a Series Topograph outfit are (1) the cinematograph camera proper, (2) the driving mechanism, (3) accessories. The camera in its turn consists of a shutter case and suspension device, an exchangeable slide case, and a removable tube and lens system of 50 or 25 cm. focus. The slide case comprises a slide with unexposed film, a film-guide, exposing window and pressure plate, and a slide for the exposed film.

The drive comprises a dynamo, either coupled direct to the engine or driven by a propeller, and an engine and change gear, allowing six different speeds in the succession of views to be obtained. The accessories comprise everything required for taking and developing cinematograph views and preparing the map or topographic sketch.

It may be said that the surprising usefulness of the apparatus was for the first time evidenced during the Somme battle in 1916 At the beginning of the latter the German airmen found greatly superior Allied air forces gathered against them, completely checking their activities and preventing them from getting an insight into the Allies' artillery positions, even their own lines being practically concealed from them This situation, difficult in itself, threatened to become critical in the absence of aerial reconnoitering, the more so on account of uncertainty about the distribution of the enemy artillery and no systematic fighting could be conceived of, when a series topograph, intervening at the emergency, proved able to alter this state of affairs. Though on account of the strong Allied air forces only a few flights beyond the front could be made by German aviators, the results so obtained proved so valuable that a complete change in fighting conditions was brought about, the German defence again beginning to assert itself

Another most instructive instance of what the apparatus is able to achieve is afforded by the aerial surveying of Southern Palestine carried out in the summer of 1917, that is, previous to the British occupation, by Lieutenant Jancke, who, in spite of particularly adverse circumstances, in less than six weeks obtained a map perfectly sufficient for strategical purposes of that so far unexplored country

Major Schroeder Resigns

Maj. R. W. Schroeder, A.S., holder of the world's airplane altitude record, has resigned his commission He had recently been reduced to the rank of captain.

Disposition of Power Plants on Airships

By R. H. Upson

Chief Aeronautical Engineer, Goodyear Tire and Rubber Co.

In a broad sense, nearly all the structural problems of airship design are due directly or indirectly to the power plants. One of the greatest of these is concerned with the mere location of power units on a large airship The difficulty is due to the following conditions:—

1. (a) To secure the most uniform loading, the different weight items should be strung out as much as possible from front to rear

(b) For convenience of operation, the power plants should be grouped as near together as possible.

2. (a) To save resistance and structural complications, the motors should be placed one behind another.

(b) Propulsive efficiency demands that each propeller operates on undisturbed air

3. (a) For efficiency and comfort, the propellers are best placed toward the rear

(b) For maximum safety and proper balance, the power plants should be further forwards, usually

4 (a) Propellers are more efficient with many units at low speed

(b) Engines are usually more efficient with a few units at high speed.

5 (a) Tractors are safer and easier to construct.

(b) Pushers are usually pleasanter and more efficient.

6 (a) The most important factor for propeller efficiency is to get a large total projected disk area.

(b) Structurally, this is usually possible to a limited degree only, for large propellers are very hard to mount and it is equally hard to find enough places where numerous small ones can be put.

The attempt to satisfactorily compromise these conflicting items is the basis of many power plant arrangements, the most important of which we will classify as follows.

1. *One Engine* In car, either tractor or pusher (Nearly all blimps are in this class

2. *Two Engines*
   - (a) In car (or directly against car)
     1. Tandem, tractor pusher (example British C and C)
     2. Both geared to same propeller or concentric propellers. (Rear car of R34 and Bodensee)
     3. Bevel gear drive to side propellers. (Forlanini, early Parsevals and Zeppelins, Capt. Caussin)
     4. Long shafts and universal joints with propellers at rear (Zodiac small twin)
     5. Two independent cars with a motor in each (Schutte-Lanz I)
   - (b) Engines mounted outside of car
     1 On side brackets (Navy Class C and D, British small twin, Chalais-Meudon, etc.)
     2 On single separate frame (British NS)
     3 In individual housings (This arrangement applies on most twin engine airplanes. variously proposed but not to my knowledge
   - (c) Engines inside of main envelope. (This has been actually built)
     1. Tractor and Pusher.
     2. Shaft drive to side propellers.

3 *Multiple Engines* - Usually combinations of single and twin engine groups as above
   - (a) Power eggs, each one or more engines, and enclosed space for engineer (Originated by Schutte-Lanz and now typical of Zeppelins, Parsevals, and British rigids)
   - (b) Transverse frames with multiple engines. (No existing examples)
   - (c) Long central car supporting all engines.
     1. Engines in car all geared to two large side propellers (Forlanini F-6)
     2. Engines on side brackets, set at angles to avoid interference (Italian T-34 or Roma)
   - (d) Two main cars (no existing examples)
     1. Transverse engine frame between
     2. Side brackets.
   - (e) Multiple independent engine housings mounted, *single* centralized engineer's cabin with distance instruments and controls. (Most multi-engine airplanes are of this type)
     1 Outside envelope, direct connected propellers
     2 Inside envelope, shaft drives.

In the present state of development it is impossible to say which is the best. There are certain distinct tendencies at the present time which are sufficiently general to be very instructive. But even these should not be taken as sure indications for the future as the basis on which they depend might easily be entirely reversed by comparatively slight improvements in the methods or materials of construction and operation.

Elimination of Gearing

The most noticeable of these present tendencies is to eliminate shafting and gears of all kinds. This practically eliminates any chance for efficient tractor-pusher units on any job like an airship where the "ship" is high. Another point more strongly insisted upon to-day, is the importance of not having interferences between different propellers. In many cases the important matter of gearing down large engines to improve propeller efficiency, has been temporarily set aside on account of the weight and complication of present gear constructions. The desire for simplicity is further illustrated in Italy by the almost entire desertion of their beautifully reversible pitch propellers.

The chief use of gearing at the present time is to permit putting two engines in one power egg where they can be attended by a single engineer. It is to be hoped that with the increasing reliability of engines, this paradoxical arrangement may give way in the future to something like item (e) above.

THE 320,000 CU. FT. AIRSHIP C. M. 5, PURCHASED IN FRANCE BY THE GOODYEAR TIRE AND RUBBER CO. THE POWER PLANT CONSISTS OF TWO 260 HP. SALMSON ENGINES MOUNTED ON SIDE BRACKETS, WITH DIRECT DRIVE PROPELLERS.

Tropical Exposure of Airship Fabric*

By Guy Barr, B. A., B. Sc.

In the middle of 1914 Commodore Sueter sent for test a strip of treble fabric, similar to that used on H. M. A. "Parseval," one half of which had been doped with an aluminum dust composition, the other half being left yellow. This sample had been exposed for a month to the weather at Berbera (Somaliland Protectorate) A similar piece of new fabric was also sent for comparison. Under similar conditions as to size of specimen, rate of loading, etc., these samples gave the following figures for tensile strength —

(a) New material

Yellow half Two 2-in. test-pieces broke at

247.5 lb.	Mean, 124 lb. per in.
248 5 lb	

Doped half · Two 2-in. test-pieces broke at

254 lb.	Mean, 126 5 lb, per in.
252 lb	

(b) Material exposed 1 month

Yellow half Four 2-in. specimens gave

177 0 lb.	Mean, 88.6 lb. per in.
180 5 lb	
175 0 lb	
176 0 lb	

Doped half · Four 2-in. specimens gave

176 0 lb.	Mean, 87.4 lb per in.
178.0 lb.	
178 5 lb	
166 5 lb.	

It was noticed that with this exposed material, the outer ply began to break down locally at stresses of from 40 70 lb./in. In this respect the doped half was the worse, probably owing to its greater stiffness.

Rates of Leakage

The widths sent were insufficient for the application of the usual permeability test, but using apparatus of the type described in the Technical Report for 1912-13, page 270, the following rates of leakage were found —

New material		
Yellow half	96	Litres per sq. m. per day
Yellow half	72	
Yellow half	62	
Doped half	2 0	
Doped half	4 4	Litres per sq. m per day
Material exposed one month.		
Yellow half	.33	
Doped half	62	
Doped half	15 6	

A second sample was received later, which had been exposed for another month. The material available allowed of only one test for strength and one for permeability on each half

Yellow half (now completely bleached) gave tensile strength 75 lb./in., and permeability 30 litres per sq. m. per day

Doped half—Tensile strength, 77 lb./in

Doped half—Permeability, 22 litres per sq m. per day

In the tensile test the outer layer gave way at about 60 lb./in in the yellow half, and 35 lb./in. in the doped half.

The "tendering" of the outer ply of cotton gave rise to the suspicion that an appreciable quantity of acidity had been generated To test this, the broken yellow tensile test-piece was soaked in distilled water, and titration showed the presence in solution of acidity corresponding to 2 cc. of twentieth-normal caustic soda, i. e., a weight of nearly half a gram of acid (calculated as sulphuric acid) per square meter. This quantity of acid is quite large enough to cause the weakening observed in the outer layer

The new material of the above tests was obviously not above suspicion, so to obtain further data to compare with these results, another sample of fabric was sent to Berbera by the Admiralty, and exposed during the winter. This was also a treble yellow rubbered fabric, metallized on the outside and skinlined on the inside. During exposure the fabric was suspended clear of the ground, so that rain should not soak into the skin lining. After two months' exposure a piece was returned for test. Two other pieces were also tested after longer exposures The results of the tests made are given below; in the later tests the quantity of material was very small, so that the results are only approximate.

	New fabric.	2 mths.	3½ mths	8 mths
Permeability lts /m.²/day	6 3	2 0	>150*	16
Tensile strength, lb /in —				
Warp	108.7	110 9	92 5	65
Weft	115.8	97 0	—	—

With these figures may be compared the results of exposure tests made in Teddington on the same fabric

	Exposure August 17th December 7th	Exposure August 17th February 17th
Permeability, lts /m.²/day	0 6	1 5
Tensile strength, lb./in —		
Warp	110 2	106 1
Weft	121.2	98.2

After this exposure the skin lining was still supple and continuous, but there was evidence of considerable fungoid growth on the skin.

Tropical Exposure More Deleterious

From these figures alone it is evident that the tropical exposure is much more deleterious than the ordinary exposure of temperate climates. But the actual properties of the fabric were more changed by the exposure in Somaliland than the figures show Not only was the outer ply of cotton "tendered," giving way at a stress some 20-30 lb./in. below the breaking stress, but the gold-beaters' skin was very papery and non-extensible, yielding and splitting off from the rubber at stresses as low as 15 lb./in Hence the apparent gas-tightness is fallacious, and would be broken down by any considerable local pressure change.

The conditions of the tropical exposure, which had obviously differed in degree from those at home, were: (I) the temperature, and (2) the intensity of the light

With regard to (1), the meteorological data showed that shade temperatures of 90 deg F and over had prevailed very frequently during the daytime (in the first series, at any rate) this is some 20 deg F or so higher than the normal temperatures of English exposure The difference between the mean temperatures in the sun would be much higher The following effects might be expected from this elevation of temperature —

(a) Any chemical reaction which occurs slowly under English conditions would be vastly accelerated. An average temperature coefficient for exothermic chemical reactions is given by the common statement that a rise of 10 deg C (equal 18 deg F) doubles the velocity of a reaction, though variations from this average are frequent. Among reactions which might be thus accelerated are oxidation of the cotton or caoutchouc by the air, action of the dye-stuff or impurities therein on the cotton, action of acid generated by oxidation on the cotton

(b) Physical effects include (1) evaporation of moisture from the various plies of cotton, and from the goldbeaters' skin, of possible traces of naptha retained by the rubber, and (in the case of the doped sample) of dope solvant, (2) changes in the condition of the rubber and of the sulphur contained in the rubber layers. The free sulphur in hot-cured rubber exists in a colloidal form, which changes very gradually to the crystalline modification on the surface of the rubber The slowness of the transformation under ordinary conditions is probably due to the distance from the transition tempera-

* Reports and Memoranda No. 173, British Advisory Committee for Aeronautics.

*Presumably in this test the sample tested, which was fairly near the edge, was not completely covered with skin, or else the skin had cracked.

ture, to the smallness of the vapor-pressure of sulphur at ordinary temperatures, and to the hindrance offered by the rubber to the diffusion of the vapor of sulphur All these influences would be reduced by an elevation of mean temperature Removal of sulphur from the interior of the rubber layer to the surface by this means would also tend to increase the porosity of the rubber, thus increasing the permeability by hydrogen, and the liability to oxidation.

(2) With respect to the variation in the incident light, the data are less accurate, but can be deduced from disconnected observations. The light may vary both in total energy content and in the distribution of the energy between the different parts of the spectrum. Since we are concerned chiefly with the chemical effects of the light, and these are most pronounced with waves of short length, the difference in intensity must be considered in regard to the violet and ultra violet, i. e., waves of about 400 μμ and less. The actual wave-lengths of the shortest waves reaching the earth's surface does not appear to depend much on the latitude (e. g., Gibbs and Freer give 291 μμ as the shortest wave observed in the solar spectrum at Manila, and quote similar values for observations at Assuan, and at Berlin and Zermatt) Hence the differences to be found must be in the intensity factor only Comparisons of the intensity of ultra-violet illumination are, of course, most scientifically expressed by actual measurements of the energy of the various rays, but complete data of this kind appear to be lacking Comparative figures are, however, available for some places in the tropics, and in temperate climates, deduced from different actinometric readings. These depend, it is true, on the absorption of light of a few particular wave-lengths, and give us accurate measure of the light of all frequencies, but they may serve to illustrate the order of the differences which occur The following figures refer to an actinometer consisting of a solution of uranium acetate plus oxalic acid contained in a quartz vessel, and express the daily average of the percentage of oxalic acid decomposed per hour during the months of September, October, and November —

Manila	12.5 per cent
Khartoum	17 8 per cent.
Munich	3 4 per cent

The observations also showed that the maximum ultra-violet intensity was very nearly the same in all places (on clear days when the sun was at the same angle), the differences in the above averages being due to differences (a) in the meteorological conditions (in these months at Munich there were no "clear" days), and (b) in the number of hours during which the sun shines (the number of hours of isolation possible at the Equator is to the number in latitude 45 deg as 1 83 to 1 34) It may be pointed out that Berbera is nearer the Equator than is Khartoum, and London is in a higher latitude than Munich

The following table is taken from a text-book on Photography (Chapman-Jones) where it is quoted on the authority of Roscoe. It gives the proportional photographic activity of light on March 25th, assuming "normal" conditions —

a. m.	p m	Manchester	Cairo
6	6	0	0
7	5	0 22	1 74
8	4	5 85	20 12
9	3	18 71	50 01
10	2	32 91	78 61
11	1	43 34	98.33
Noon		47 15	105.30

Adding together the figures for each hour we get as the total for the day —

Manchester	249.2
Cairo	602.0

and from other figures —

Ireland	100.7

The Cairo figures bear to the Manchester ratio 2½ to 1 approximately, which is half of the ratio found above (for other rays) for Khartoum figures to Munich.

It is hence probable that the photo-chemical action of light at Berbera during a given period of exposure may be anything up to five or more times that in England.

As to the nature of the photo-chemical action, the following facts may be adduced —

(1) It has been found, e g, by Paterson, that exposure to light causes the insulation resistance of ebonite (highly-vulcanized rubber containing up to 30 per cent. of free sulphur) to fall very rapidly This change was proved, by some acidity determinations made by the writer, to be accompanied by and probably due to the formation of sulphuric acid on the surface of the ebonite. Both changes were very retarded by protecting the ebonite with yellow glass, i. e., were almost certainly due to the action of ultra-violet light.

(2) Acidity of the same order of magnitude (per unit area) as was found in these experiments has been found on the surface of the first yellow fabric exposed at Berbera. (See above)

(3) The bleaching of dyes is usually considered to be a photo-chemical process which is most sensitive to ultra-violet light. The dye on the Parseval fabric withstood nearly a year's exposure here fairly well, but was almost completely destroyed in the exposure at Berbera.

The experiments made in 1910 on exposure of two fabrics to the light from a quartz-mercury-arc give no conclusive data for the present purposes. These exposures were made in order to obtain comparisons between two different types of fabric, and the necessity of exposing considerable surfaces at the same time led to the lamp being some four feet from the fabrics. Under these circumstances the actinic intensity of the lamp (as given by a photographic exposure meter) was only about 1-50th of that of a bright midsummer noon sun here, i. e., as regards the actinic value of the light the exposure was probably roughly equivalent to, or possibly less than, a continuous outdoor exposure of the fabrics. By using very small permeability pieces, as had been done for the Berbera tests, and placing the samples very much nearer to the source of light, the effects should be comparable with, or, with a specially arranged lamp, considerably greater than, those due to ultra-violet light in the tropics.

Apparatus of this kind has been set up, and experiments are in progress to compare the deterioration of various types of balloon fabric when exposed to the light of the lamp, and when exposed at Berbera

Exposure tests in the tropics of the following fabrics and samples are also suggested for balloon fabrics —

(a) A chromate colored cloth, i. e., with rubber cold-cured (and containing little or no free S).

(b) An aniline dyed cloth, i e., with rubber hot-cured.

(c) An uncolored cloth metallized in several different ways, including direct spraying without any vehicle.

(d) Any or all above with dopes outside

(e) One or two of above with goldbeater's skin inside

(f) One or two of above with a yellow cotton fabric tacked over it, without rubber, or with one thickness of Wratten's "safelight" fabric.

The fabrics should, if possible, all be of similar manufacture, i. e., made from the same rubber and same cotton. Sufficient would be sent for two permeability tests and twelve tensile tests, so that one half could be returned after one month, and the remainder after two (or more) months. At the same time a piece from the same strip would be kept at the laboratory, so that the same warp threads could be tested. During exposure, (e) would be tacked over a box or frame, so that the skin should not get wet. For airplane fabrics —

½ sq yd. of doped linen (Emaillite or similar dope)

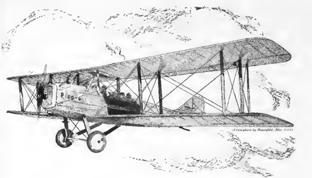
½ sq yd of doped linen (doped with size, or casein mixtures)

General

Pieces of cotton, linen and silk, canvas without filling or proofing

Actinometer readings might be taken in order to get more precise information concerning the intensity of ultra violet light in the tropics, as compared with this country

Further comparison pieces of each fabric sent out might be stored during the period of exposure stretched out in a shed, with a roof similar to that which would be used on the airship shed. This would indicate whether the heat and drought, etc, are likely to cause deterioration apart from exposure to strong light and dew It is hoped that some of the materials (e) or (f) may stand all the tropical conditions fairly well.



(From photo by Rosenfeld, New York)